NASA HEADQUARTERS NACA ORAL HISTORY PROJECT

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NASA YEARS

At the end of the greatest war the world had seen, Dot and I were among the survivors. More importantly, we were on the winning side. Life would have been unbearable for the losers had the Nazis won.

As with others of our generation (termed by some as the greatest), we were concerned with the question: what do we do now? Being eligible for a partly financed college education under the post war GI Bill, that certainly was an option. But we thought it might be best to build up some savings to carry us through a period of uncertainty. While living with my parents in Springfield, Pennsylvania, right after my discharge from the Army Air Corps, I went to the local employment office and found a job as a worker in a storage facility. This was a really unsatisfying occupation which we regarded as only a temporary measure.

Soon after that, we took a trip to Hampton, Virginia, to visit Dot's parents. While there, I stopped in at an employment agency and found that a civil engineer, R. F. Pyle, was looking for an office worker who could make drawings. I was mostly self-taught, but felt that I might qualify. During a visit to his office in downtown Newport News, I was asked to show my drafting skills.

My efforts were found to be acceptable and I was offered a job paying the magnificent salary of $35 a week. I accepted.

At R. F. Pyle's, under his direction, I learned to make "plots" of property to accompany deeds recorded in the local courthouses. I also assisted in land surveying, mostly holding the plumb bob or clearing the line of sight. But, I did learn how to use the level and transit. My major project was preparing drawings for the construction of The Patrick Henry Airport in Warwick County.

Dot found work at The National Advisory Committee for Aeronautics (NACA) at Langley Field. She worked as a secretary at the 7 x 10 Foot Tunnel. With this income and living with her parents, we soon accumulated enough funds for a down payment on a home of our own at 430 Allegany Road in Hampton. All of this time, we got around by using public transportation, trolleys and buses. Back then, the Peninsula had a well-organized and functional public transportation system. After moving to our new home we soon purchased a car, a 1947 Ford. I had just enough experience to pass the test and get a driver's license. Then, I taught Dot and she got her license.

After living about two years in this home and accumulating some savings, I found out about a program at the College of William & Mary in nearby Williamsburg that seemed tailored to my desires. Students could take two years of pre-engineering courses there and then transfer to MIT [Massachusetts Institute of Technology, Cambridge] in pursuit of an engineering degree. There was also a shuttle bus that provided transportation to and from the college. Finally, there seemed to be a way to achieve my ambition. After enrolling in W&M using the GI Bill, I found I could schedule classes so as to go to school three days a week (Monday, Wednesday, and Friday) and work three days (Tuesday, Thursday, and Saturday). The plan seemed to be working well; the problem of moving to Yankee Land could be tackled later.

After completing the two years of pre-engineering in the spring of 1950, Dot and I decided to explore the idea of my going to an engineering school in the south. On a visit to VPI [Virginia

Polytechnic Institute (Virginia Tech), Blacksburg], we found that my preparatory courses were acceptable. We also found that I could arrange a schedule that would allow me to have a part-time (but low pay) job as a lab assistant in the Mechanical Engineering Department. I chose Mechanical Engineering rather than Civil or Aeronautical, because the class schedules allowed me to meet graduation requirements at an earlier date. Dot found a job as a secretary in the Department of Agriculture.

We found a way to do it! We sold our house and moved into an apartment above the J. D. Hardy Esso Station in Blacksburg. It was not a completely pleasant situation, but we survived. Being close to the action, we got into college activities like plays, concerts, and sports more than we were able to do at W&M. The time went quickly. Then, when I graduated in June of 1952, there came the question of "What Next?"

Since we both liked the Virginia Peninsula, employment at the NACA Langley Aeronautical Laboratory was an obvious choice. I arranged to have an employment interview there a few days after graduation. Because my degree was in Mechanical Engineering, the employment office first offered work in the Engineering Department where I would first work as a draftsman and be concerned with the construction of new facilities. This did not appeal to me, and I asked about other possibilities. It turned out that a new facility, the 4 Foot Supersonic Pressure Tunnel, had just become operational and was looking for staff. The branch head, Don [Donald D.] Baals, gave me a tour of the tunnel and inquired about my interests and qualifications. I guess my experiences in the Army Air Corps and my interest in aviation, including model building, helped make a favorable impression. I was offered a job and I accepted.

We lived for a few months in an apartment in Hampton, but soon decided to get a place of our own. We bought a lot in Riverside in Warwick County near the James River, 122 Dogwood

Drive. Then we found a contractor, selected plans and had a ranch style home built. It wasn't long before we had children, Debbie and Cathy. We had additions made to make living more comfortable for us. Also, I made some additions myself; an activities room, a greenhouse, a playhouse, and a storage shed.

My first assignments at NACA included a lot of shift work helping to conduct wind tunnel experiments. Often I worked the night shift – from 4 to 12 p.m. as I remember. These wind tunnel tests were overseen by research engineers who had the expertise and knowledge necessary to answer the questions brought to NACA by Army and Navy officers heading aviation units. Airplane models tested in the 4 Foot Tunnel had about a 2-foot wingspan. The forces on the model were measured by strain gauges attached to the model support system. When these gauges were affected by forces on the model, an electrical current passing through them would vary in intensity in proportion to the forces. With proper calibration of the instruments that measured the current, the magnitude of the forces could be determined.

The process of finding the lift, drag, and pitching moment required a good bit of calculation. This work was performed by "Computers." Before the mid 1950's, Computers were people (not machines) and almost always were women. The 4 Foot Supersonic Pressure Tunnel Branch had a Computer Office that employed about a dozen women. They used "calculators" to perform the mathematical operations. Friden and Monroe were two of the manufacturers that made the machines. The test engineers would prepare calculation sheets with rows and columns (like present-day spreadsheets) for the "computers" to fill out. The engineer would fill in the left columns with measured gauge readings and in succeeding columns headings would stipulate the mathematical operations to be performed. The "computers" would then go to work.

Later, after the complete reliance on humans to communicate with the machines, other methods were developed. One was the use of punch cards or Hollerith cards named after the inventor [Herman Hollerith]. With this method, I could create on my own the data sent to the computer. A special typewriter connected to a punch machine was employed. The big problem here was the great potential for error on the part of both the machine and the operator. The system was not very reliable. Fortunately it was replaced. In the late 1950s, a new system allowing a direct connection of the research engineer with the machine was developed. The system was called FORTRAN. With the help of programmers, I was able to learn how to use it. There were very strict rules and it took time. This was the tool I used from then on to create computer programs and provide solutions to aeronautical engineering problems. Electronic connections allowed me to sit at my desk and communicate with computers in a laboratory run by the NACA Analytic Computing Division.

In time I was promoted to a position where I was responsible for conducting some of these tests. The first that I remember vividly was instigated by a German engineer, Adolf Busemann, who came to the U.S. under "Operation Paper Clip" along with many other scientists. At that time, test pilots at the Dryden Flight Research Center [Edwards, California] were experimenting with airplanes capable of supersonic flight. Aviation enthusiasts were then very interested in "breaking the sound barrier" and the accompanying "sonic boom." Dr. Busemann had an idea of how the boom could be reduced by shaping the fuselage to direct the strongest shock waves off to the side instead of directly below to the ground. The special shape featured a vertical leading edge and a horizontal trailing edge connected by triangular planar surfaces. He termed the phenomenon "Angel Boom." Angels in heaven would hear it, but people on earth would not.

Since, at the time, I had not much else to do, I was given the responsibility of devising and conducting an experiment that would test his theory. I had NACA shops build a one inch long model and a sting support. The sting is just a small diameter rod that attached the model to a motor driven mechanism that moved the model fore and aft in the tunnel test section. A very small diameter orifice in a boundary layer bypass plate mounted just off the side wall in the tunnel test section would be used to measure the pressure field created by the model. In later wind tunnel tests, a small orifice in a slender conical probe was found to give more accurate results.

While preparing for this test program, I found that an opposing theory had been developed earlier by Dick [Richard T.] Whitcomb, another Langley Research Center engineer. His idea was that at large distances the flow field created by a body of any shape would become symmetric. He also said that the drag of that body would be the same as that of an equivalent body of revolution. This theory became known as the "Area Rule." The equivalent body of revolution would be defined as bodies of circular cross section having the same area as cross sections of the actual shape intersected by cutting planes perpendicular to the flight path at all stations along the body axis. When I learned of this, I added other models to the test program, including an equivalent body of revolution representing the special wedge shape.

When the tests were conducted, it was found that although the shock field near the special wedge shape model was extremely directional, it approached a more uniform distribution as the distance from the model increased. It was clear that at large distances comparable to flight altitudes, the pressure field would be nearly symmetrical. And in fact, the flow field produced by the equivalent body became increasingly similar to that of the special shape as the distance increased. In writing the report describing the tests, I placed the emphasis on confirmation of the Area Rule rather than refutation of the Angel Boom.

After this experience and after conducting other tests of existing supersonic aircraft and proposed supersonic transport designs, I became intrigued by the sonic boom phenomena and read technical reports discussing what was then known. I found that a British scientist, G. B. Whitham, had studied the problem of predicting the strength and distribution of the flow field and relating it to the airplane size, shape, weight, and flight conditions. It was both a mathematical and a graphical procedure that required a good bit of detailed work. I saw that the process could be handled by a properly constructed set of steps in what engineers call an algorithm and that this process could be programmed so as to have a computer do the hard work.

In the mid-1950’s computers were just coming into use. They used vacuum tubes similar to those then used in radios and were quite large, the size of refrigerators. They also produced a lot of heat and had to be cooled. At NACA, air conditioning was used in computer labs before it was considered for use in making office workers more comfortable in the oppressive Virginia summers. Getting information into computers, having it processed, and extracting the answers has always been complex. Computer pioneers were then developing special languages that enabled humans to communicate with the machines. Trained specialists in this field were called programmers and again were mostly women.

To develop the program needed for sonic boom prediction, I worked with programmers. I remember Sadie Livingston who was very helpful. I provided a description of the process (the algorithm) including the method of solving the equations involved. The programmer then communicated this information to the machine. The programmer would type the information on special typewriters that converted it to digital form (1s and zero’s) recorded on tape stored on large reels, about a foot in diameter. This information, sometimes called a code or a program, was the read into the computer. The data to be processed was fed in on a separate tape. Answers provided by the machines were recorded as an output on printed paper. Usually it was a two day overnight process to get answers for a particular case.

The sonic boom computer program that I developed provided pressure signature estimates only for a uniform atmosphere. Of course the real Earth's atmosphere is far from uniform. The program could, however, provide the necessary airplane information that was needed as an input to programs that tracked the development of the pressure field as it propagated through the atmosphere. The propagation program that we used was developed by Wallace D. Hayes. My program by itself would also allow the comparison of the boom characteristics of competing aircraft and could be used to show the effect of proposed design changes.

The original sonic boom prediction methods evolved over the years as the technology developed. It was soon found that airplane lift as well as drag contributed to the sonic boom, and as methods for prediction of lift distribution were developed, the methods were revised to include that effect. The early methods provided only what was called a far field solution; it was assumed the pressure signature on the ground would evolve into a simple "N Wave," an initial shock, followed by a linear decline to negative pressures, followed by a second shock to restore ambient pressure.

In later years, during the National Supersonic Transport [SST] Program, it was found that there was some possibility that a more complex "Near Field" signature would persist to the ground. This discovery also provided some hope that airplane shaping might modify the signature so as to reduce the intensity of the boom. Accordingly, as the technology developed, the methods were modified so that near field signatures could be calculated. The program was used extensively in the National Supersonic Transport Program, but there was found to be little possibility of sonic boom reduction through shaping. Extensive comparisons of measured wind tunnel signatures and ground measurement in flight tests showed that the prediction methods were reasonably accurate.

I should mention that in 1958, NACA became the National Aeronautics and Space Administration (NASA). This was partly in response to Russian advances in space technology. For me, the transition was smooth; daily activities went on as before. I was however offered a position in Washington, D.C., [NASA] Headquarters, where I would work on space projects. Dot and I made a trip to Washington to consider the possibilities. After seeing the traffic congestion and the high costs of housing, we decided to decline the offer. Another factor was that I enjoyed aeronautical research and was reluctant to enter a whole new field.

In the late 1950s, aeronautical engineers began to consider seriously the prospect of routine supersonic flight which would include not only military aircraft but also commercial supersonic transports. I became involved in this work when I was assigned to conduct wind-tunnel tests of a highly swept twisted and cambered wing designed for efficient flight at a Mach number of 2.0. In this, I worked with Clint [Clinton E.] Brown and Ed [F. Edward] McLean who designed the wings and also were employed at Langley. These tests showed that a wing with the proper twist and camber did indeed provide better performance than a simple flat wing. However, the measured drag due to lift was not as low as indicated by the simplified linearized theory then in use. It was found that the airflow over the wing was not as clean and smooth as assumed in the development of the theory. There appeared to be regions of the wing where the flow separated from the surface producing a drag penalty. Although a specified amount of twist and camber was predicted to maximize the lift to drag ratio, it was found that the best performance occurred with a wing having only about half of the twist and camber predicted by the theory. The shortcoming was attributed to the flow separation. I am told by Joe [Joseph R.] Chambers, who is writing a history of NACA and NASA logos, that this wing design became an influence on the selection of the red “slash” in the NASA Meatball Insignia.

After being involved in the experimental aspects of the prediction and optimization of wing performance, I became interested in the theoretical and mathematical aspects. I saw that here too, as with sonic boom, there was a way to perform the tasks in a much more efficient way. With the help of computer programmers and other engineers, notably Wilbur [D.] Middleton, I began my development of computer programs for wing evaluation and design. While engaged in this effort, I realized that I needed to increase my knowledge of higher mathematics. I took night classes given by the University of Virginia at Hampton High School that included advanced calculus, differential equations, and simultaneous equation solution.

Theoreticians including Robert Jones, Warren Tucker, and Fred Grant had developed methods for predicting and optimizing wing performance. The methods required intensive manual deskwork in the solution of simultaneous equations. These equations provided a relationship between the lifting force generated by a small localized part of the wing (a wing element) and the influence of all other wing elements in creating the flow field in which it was immersed. The manual process could be carried out using only a rough approximation of the wing plan form, took a great deal of time, and was subject to human error. With electronic computers doing the hard work, a much more detailed representation of the wing plan form and shape could be accommodated, while requiring much less time, and lessening the chance of numerical errors.

After development of the computer programs, they were tested by comparing predicted performance of specific wing shapes with measured wind tunnel results. Again, it was found that the prediction of performance for optimized wings was overoptimistic due to flow separation. Even with this shortcoming, it seemed to be worthwhile to publish technical reports describing the methods used in the design and evaluation, and the comparisons with measured results. NASA also provided copies of the programs to potential users. Occasional phone calls from airplane manufacturing company engineers let me know they were being used.

The original methods for design and analysis of supersonic wings were published in the mid-1960s. Improvements and additional capabilities were added through the 1970s. At the same time, computer methods for estimation and minimization of other drag sources, skin friction and wave drag due to thickness were being developed by other NASA research scientists. These programs saw extensive use in the National Supersonic Transport Development Program directed by the Federal Aviation Administration. Warner Robins, also NASA Langley, followed these developments carefully and used them in his development of advanced SST designs. One of these the SCAT 15-F, received a U.S. patent. Sadly, this effort did not result in the development of viable supersonic transports. The sonic boom which restricts supersonic flight to over water flight and the increased fuel consumption due to high supersonic drag are the main reason that supersonic transports are not flying today.

In the mid-1970s, I became more determined to find the cause of the discrepancy between theory and experiment. The problem could be identified as the failure in real flow to achieve as much leading edge thrust as the idealized theories predicted. Leading edge thrust (a force counteracting the drag on the rest of the wing) arises from flow acceleration and low pressures as the air encountering the wing on the lower surface just aft of the leading edge flows forward and around the leading edge before again flowing aft.

With the help of Bob [Robert J.] Mack and Ray [Raymond L.] Barger, I made a study of experimental wind tunnel data for two dimensional airfoils which clearly showed the deficiencies of linearized theory. An exhaustive study of the experimental results and comparisons with theoretical predictions showed that the over prediction of thrust could be related to wing geometry and flight conditions and could be predicted. Finally in the late 1970s, a method of estimating attainable leading edge thrust was added to the wing programs. A NASA Technical Paper number 1718 entitled "Estimation of Wing Nonlinear Aerodynamic Characteristics at Supersonic Speeds" published in 1980 describes the methods, outlines their use, and shows comparisons with experimental results.

In 1980, I retired from NASA; but real retirement didn't last long. Soon after retirement, I was offered a job as a consultant by Kentron and I accepted. This employment as a consultant continued under other contractors until 2004 when I retired from my last employer, Lockheed. During this time, I continued to concentrate on wing design and evaluation. I modified the wing programs to include two surfaces, a wing and horizontal tail, or a wing and a canard. Also the methods were extended to subsonic as well as supersonic speeds. Mike [Michael J.] Mann, Christine [M.] Darden, and Barry [Barrett L.] Shrout collaborated with me in this work. As a contractor, I was able to write and have published NASA papers. Descriptions of the computer programs, comparisons with experimental results, and recommendations for their use are given in NASA Technical Papers numbers 2961, 3202, and 3637.

The partial retirement allowed Dot and I to pursue our hobbies. One was golf; we travelled around the country playing at various resorts in North and South Carolina, Georgia, and Florida. The other hobby was simply traveling. We went on tours of Mexico, Hawaii, Australia, New Zealand, the British Isles, the Scandinavian countries, and we took a Rhine River cruise. Dot passed away in 2004. Now I am living in Twin Lakes, a retirement community in Burlington, North Carolina.

The End

Harry W. Carlson